Since the 2002 PFR, additional investigations of drainwater production, reduction measures, and quality have resulted in revised estimates of drainage quality and quantity. This section describes the results of these additional analyses. In the 2002 PFR, total annual drainflow to reuse areas for the In-Valley Disposal Alternative was estimated at 106,700 AF/year. The additional analyses resulted in a revised estimate of 69,645 AF/year for the entire study area.

4.1 DRAINAGE RATES

Drainage rates for Westlands and the Northerly Area were derived using a variety of modeling and analytical tools. The annual field drainage rates used are 0.35 AF/tiled acre for Westlands and 0.42 AF/tiled acre for the Northerly Area. After application of source control measures (shallow groundwater management, drainwater recycling, and seepage reductions) and adding in uncontrolled seepage in the Northerly Area, the corresponding drainage rates to the reuse facilities are 0.25 AF/tiled acre for Westlands and 0.54 AF/tiled acre for the Northerly Area. After reuse, the drainage rates for treatment and disposal decrease to 0.134 AF/tiled acre for Westlands and 0.164 AF/tiled acre for the Northerly Area.

The rate at which water will need to be drained off the fields to maintain arability of the soil has been estimated using two methods: field studies and regional groundwater modeling. The following sections discuss the development of the drainage rates using both of these approaches. Results from both approaches were considered in the selection of the final drainage rates and quantities for reuse and disposal shown in Tables 3-8 through 3-10 and Table 5-1 for the four In-Valley Alternatives (with and without land retirement). Drainage flows from the field estimates were higher than those from the groundwater modeling efforts and were used to develop rates for Westlands. Expected drainage rates for the Northerly Area were based on a variety of factors including monitoring data from the Grassland Area Farmers and Grassland Bypass Project, regional groundwater modeling results, and professional judgment by the Technical Team members.

4.1.1 Field Estimates

The drainage collector system that will be used to carry drainwater to the reuse areas needs to be sized properly. Reclamation's approach to the sizing criteria was to calculate an expected future peak daily drain discharge and use that discharge as the pipeline design criterion. Computing a future daily peak drainage discharge required estimating the amount of drainwater produced by on-farm subsurface drains. Many miles of surface and subsurface drains exist within the Northerly Area, so the estimated future flows are considered to be similar to the present day flows with some adjustments for control of seepage losses. The estimated future on-farm drainflows in Westlands required additional assumptions and estimates of what the future irrigated agriculture operations might become.

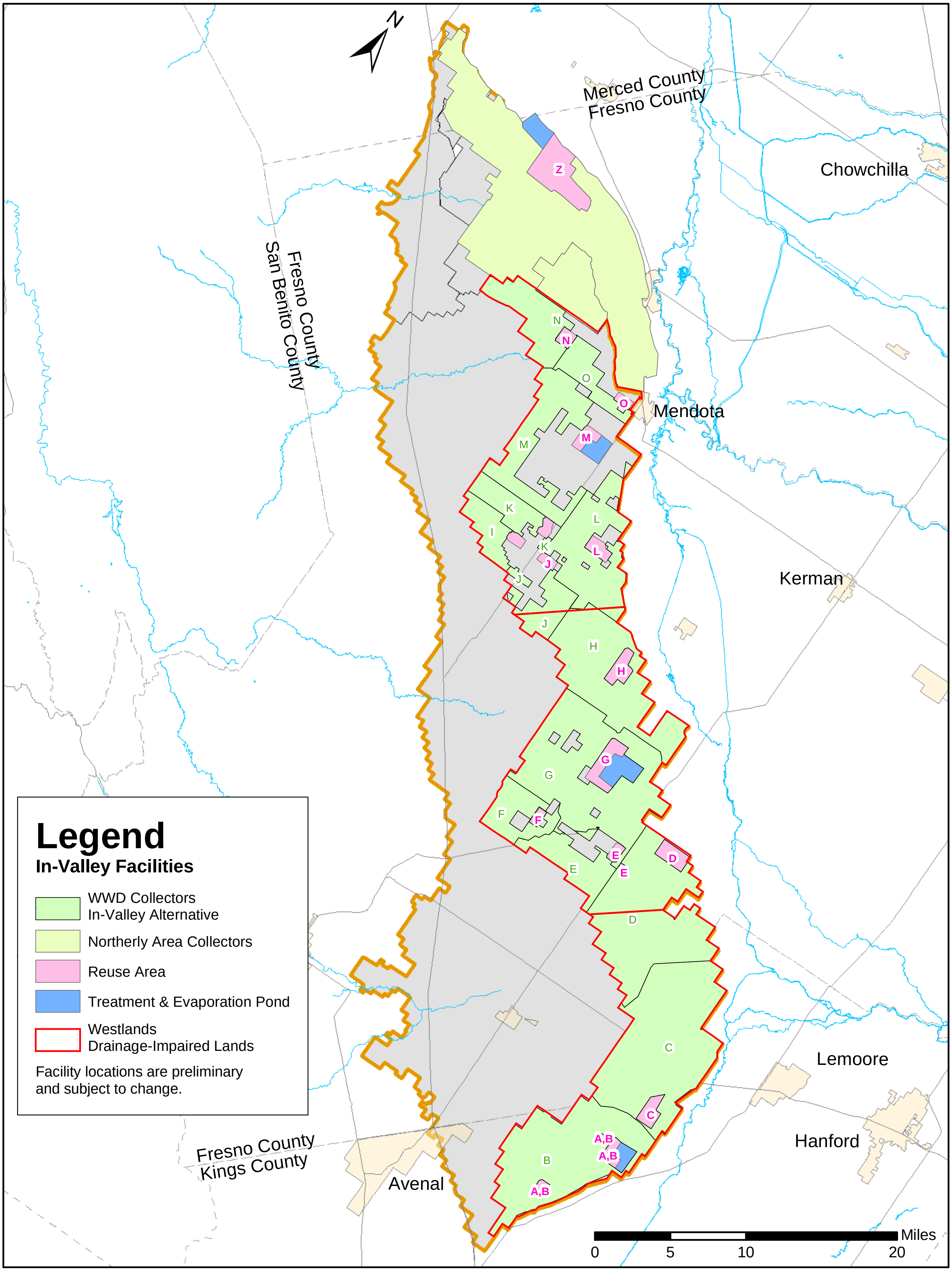
Assumptions regarding what the future irrigated agriculture might become are very important to the estimated return flows from the on-farm drains. Issues as simple as 'What crops are going to be grown?' have a significant impact on drainage return flow quantity and quality. Several discussions and telephone conference calls with the Technical Team have been required to arrive at a set of reasonable assumptions that provide the basis for the drain return flow that can be used both for collector pipe sizing and reuse area sizing, and finally treatment plant and evaporation basin sizing. The Technical Team consisted of a variety of knowledgeable people from URS

Corporation, HydroFocus, Western Resource Economics, Summers Engineering, Westlands Water District, California Department of Water Resources at Fresno, and Reclamation's South Central California Area Office, Mid-Pacific Regional Office, and Denver Technical Service Center. The Technical Team was utilized to discuss, and agree upon, several issues relating to the irrigation and drainage components of this project.

The approach used by Reclamation for the collector size criteria relied upon the soil and water setting with an estimate of the expected drainage from irrigated agriculture. The soils data of the area (Westlands) are fairly detailed, and the water supply for irrigation is well defined. The primary unknown parts of this effort are the types of crops grown; the mix of crops and how many acres of each; the irrigation application efficiency; and the influences of other items such as seepage, water table flow from other areas, and influence of well pumping. Estimates of the crops and crop mix, and the expected irrigation efficiency have been completed; however, the contribution of seepage, water table flow, and well pumping have been evaluated by the regional groundwater model analysis (Section 4.1.2).

The crop mix has been developed to reflect a mix of alfalfa, cotton, sugarbeets, small grains, tomatoes, and vegetables. Various planting and harvesting dates that are common to Westlands have been used. The computation of various water delivery times to replenish the soil moisture depletion from the actively growing crops is also involved. The on-farm drains have been assumed to be constructed at a depth and spacing that provides for proper water table control for the crop and irrigation sequence that produces the most water table recharge. The crop with the most water table recharge is cotton, so the return flows for the collector system design are based on the drain spacing for cotton. However, less than 100 percent of the area is planted in cotton. When the other crops in the cropping pattern are grown, the drainage return flows are computed using drains that have been spaced for the cotton crop.

Reclamation's investigations into drainwater volume are focused on field studies for the sizing of drainwater reuse areas in Westlands subareas (outside of the Northerly Area). They serve as a check for estimates produced from the groundwater model. Appendix C, Drainwater Reuse, provides a comprehensive discussion of the sizing of the reuse areas. Figure 4-1 illustrates the Westlands and Northerly drainage service areas and potential reuse sites (A through Z).



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URS	San Luis Drainage Feature Re-evaluation 17324004	Drainage and Reuse Areas In-Valley Alternative	Figure 4-1

Results of Reclamation's investigations for drainage volume are incorporated into Table 4-1 with inflow into the reuse areas. The drainage volume from the commercially irrigated lands is reduced by implementing source control measures. (Source Control Memorandum [URS 2002]) Two specific source control measures have been included in these calculations: shallow groundwater use by crops, and recycling of drainwater back into the irrigation water supply. The source reductions are estimated on an AF/irrigated acre basis, and are applied before the drainwater reaches the reuse area. After source reduction, a total of 40,185 AF/year of drainwater would flow to the 15 Westlands reuse areas, a rate of production of 0.25 AF/drained acre. An additional 29,460 AF/year of drainwater would flow to the Northerly Reuse Area (Area Z) from the Northerly Area.

Table 4-1
Drainwater Inflow to Westlands and Northerly Reuse Areas

Reuse Area	Commercially Irrigated Gross Acres[1]	Commercially Irrigated Tiled Acres[2]	Annual Drain Volume[3]	Source Reductions		Reuse Inflow (AF/yr)
				Groundwater Management (AF/yr)[4]	Recycling (AF/yr)[4]	
A	7,035	4,690	1,642	-136	-352	1,154
B	26,440	17,627	6,169	-512	-1,322	4,335
C	24,294	16,196	5,669	-470	-1,215	3,984
D	37,633	25,089	8,781	-728	-1,882	6,171
E	9,828	6,552	2,293	-190	-491	1,612
F	8,622	5,748	2,012	-167	-431	1,414
G	36,378	24,252	8,488	-704	-1,819	5,965
H	28,001	18,667	6,534	-542	-1,400	4,592
I	5,070	3,380	1,183	-98	-254	831
J	6,920	4,613	1,615	-134	-346	1,135
K	6,660	4,440	1,554	-129	-333	1,092
L	11,460	7,640	2,674	-222	-573	1,879
M	20,730	13,820	4,837	-401	-1,037	3,399
N	10,880	7,253	2,539	-211	-544	1,784
O	6,080	4,053	1,419	-118	-304	997
Z[5]	5,510	5,510	2,397	-159	0	2,238
All Areas	251,541	169,530	59,806	-4,921	-12,303	42,582

Source: Appendix C, Table C-4.
Notes:
[1]Acreages area approximate based on collection area and will change after completion of the feasibility design. Some rounding up to full quarter sections is included.
[2]Based on an estimated two-thirds of the Gross Area.
[3]Based on annual drainage production rate of 0.3465 AF/acre.
[4]Estimated annual reduction is prorated to collection size of each reuse area.
[5]This portion of the Northerly Area would have new collectors installed as part of the project.

Discharge from reuse areas would be combined and pumped to treatment plants for all of the In-Valley Alternatives (with and without land retirement). The average annual discharge from the reuse areas is the supply for the RO treatment process, and is estimated at 12,260 AF/year for the Westlands North, Westlands Central, and Westlands South reuse areas with groundwater management and recycling drainwater reduction measures, and 8,856 AF/year for the Northerly Reuse Area with groundwater management, drainwater recycling, and seepage reduction measures (Appendix C, Tables C-5 through C-7).

4.1.2 Groundwater Model Estimates

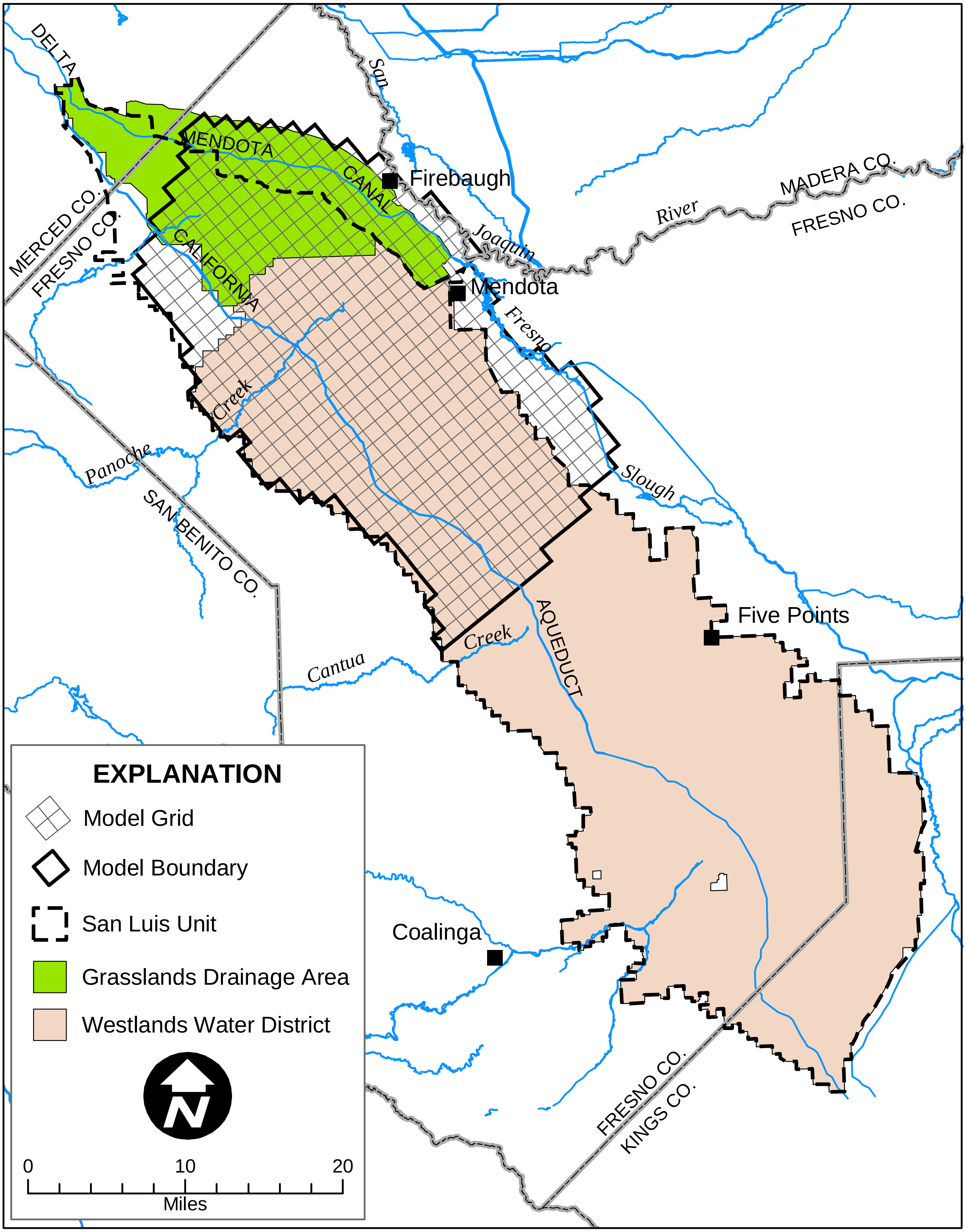
A transient, three-dimensional, regional groundwater-flow model was used to simulate changes in western San Joaquin Valley groundwater storage and water table depths under different water and land use scenarios. The USGS developed the model for the San Joaquin Valley Drainage Program (Belitz et al. 1993). HydroFocus, Inc. (1998) evaluated model-projected groundwater levels and drainflow during the period 1989–97. They updated boundary conditions, recharge, and pumpage data and concluded model results are acceptable to evaluate long-term changes in water-table depth.

The groundwater model simulates hydrologic conditions in both the upper semiconfined and lower confined aquifer systems. It is spatially discretized into more than 550 square-mile model cells (Figure 4-2), and represents about 212,500 acres of the approximately 604,000-acre Westlands Water District, and about 81,500 acres of the 97,400-acre Northerly Area.

4.1.2.1 Model Assumptions

The model utilizes mean annual recharge and pumpage data to project long-term annual changes in groundwater storage and water table depth. The model simulates water table recharge and groundwater pumpage within nine water budget subareas (Figure 4-3). Most of the subareas correspond with individual water districts; however, Westlands is subdivided into three subareas based on depth to the water table (10 feet below land surface or less, 10 to 20 feet below land surface, and greater than 20 feet below land surface). Specified recharge and pumping rates are reported in Appendix A, Table A-1, and relevant data sources and assumptions are summarized below:

- For current conditions, annual district-wide recharge rates were estimated using information from Table 5 (Fraction of Deep Percolation by Irrigation Method) from the Source Control Memorandum (URS 2002). In Westlands, the spatial distribution of water table recharge was weighted based on the recharge distribution reported by Belitz et al. (1993).
- Groundwater is a water supply within Westlands, but not within the Northerly Area. In Westlands, simulated annual groundwater pumping is maintained constant at 175,000 AF/year, which is equal to the average private supply reported in Westlands' Water Needs Assessment (Reclamation 2003b).



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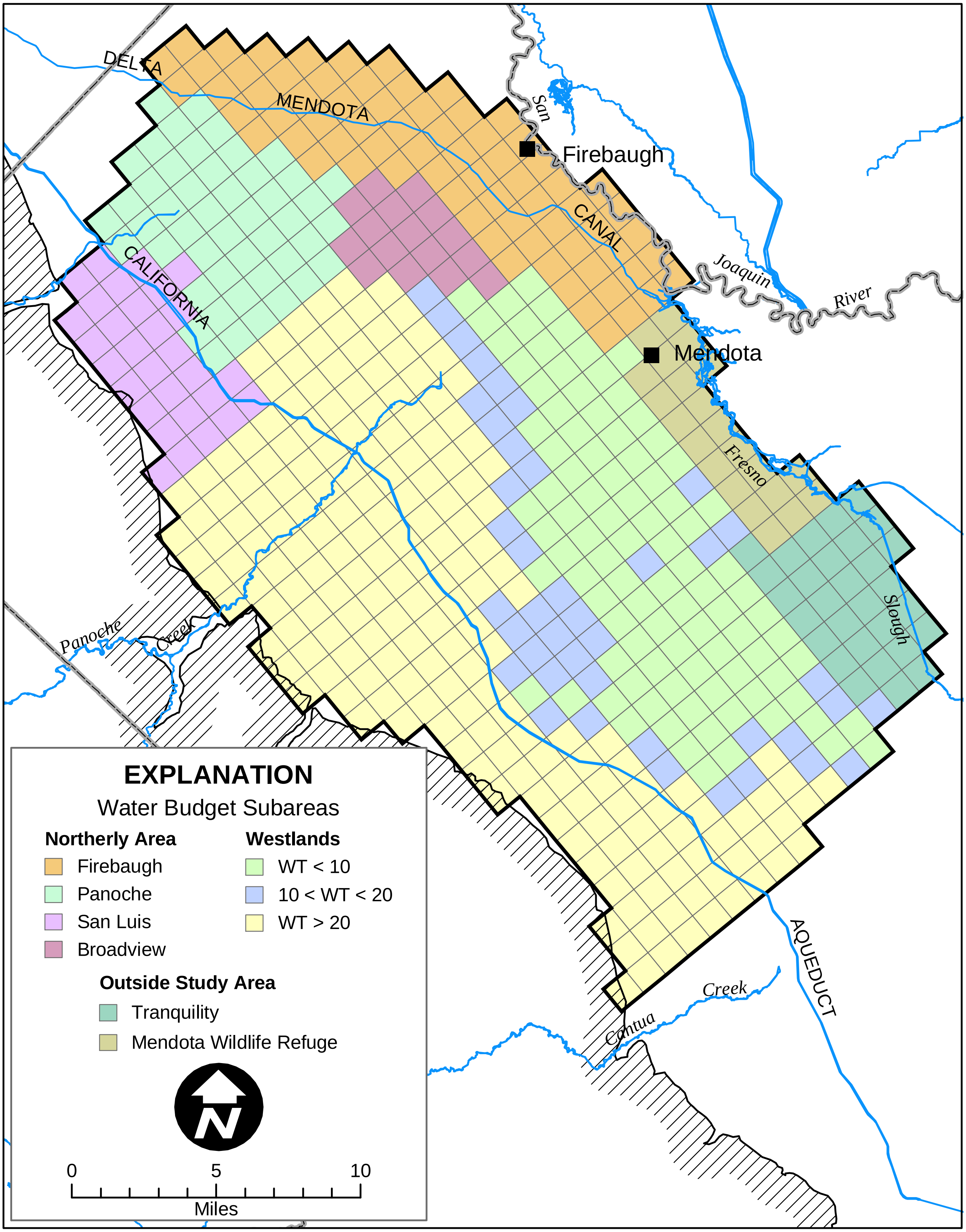
HYDROFOCUS INC. Solutions for Land and Water Resources	Model Grid	Figure 4-2
PROJECT: 5017	DATE: 4/22/04	



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Water Budget Subareas

Figure 4-3

PROJECT: 5017

DATE: 4/22/04

Several assumptions were made to simplify model input data set development and construction. These assumptions relax some of the approaches employed for previous analyses of the In-Valley Disposal Alternative. Most of these simplifications are common to all the scenarios assessed for the land retirement analysis. The key simplifications are summarized below:

- Drainage system installation and land retirement were implemented instantaneously rather than phased in gradually over a 5-year period.
- Water table recharge beneath reuse facilities and evaporation basins was not included.
- Seepage control measures in the Northerly Area were not included. Seepage control measures reduce water table recharge in the Northerly Area by 4,200 AF/year.
- New drainage systems planned for the Northerly Area (3,007 acres) were not included.
- All new drainage systems are conventional in design; however, 25 percent of the new drainage systems planned for Westlands and 10 percent of the new drainage systems planned for the Northerly Area are assumed to be designed to manage shallow groundwater (for example, using closer drain lateral spacing and shallower drain lateral depths).

4.1.2.2 Drainflow Estimates

Drainflow is the net result of water table recharge, evaporative losses from the shallow water table, and natural drainage (vertical downward movement of groundwater past the drain laterals); regional processes (water table recharge and pumping) influence the underlying distribution of hydraulic head and the resulting natural drainage.

Beginning in 2005, new subsurface drainage systems are assumed in the model to be installed in all areas of Westland's drainage-impaired area having a simulated water table within 7.5 feet of land surface. After 2005, drainage systems will gradually be installed within the remaining drainage-impaired area when the simulated water table reaches a depth of 7.5 feet or less.

Simulated drainflows were adjusted to account for processes not directly simulated by the regional groundwater flow model including:

- Scaling the model drainflow to account for drainage-impaired areas not within the model domain. This resulted in multiplying the Northerly Area simulated drainflow by a factor of 1.12 and Westlands simulated drainflow by a factor of 2.71.
- Adjusting the annual drainflow estimates to account for temporal variability not explicitly represented by the model. The model utilizes annual stress periods to estimate average annual drainflow, but relatively greater volumes of drainwater are produced during and immediately following irrigation than are expected from annual drainflow conditions (Deverel and Fio 1991; Fio and Deverel 1991). The scaled simulated annual drainflows for the Northerly Area and Westlands were multiplied by 1.5 to account for temporal processes based on comparisons with measured and modeled drainflow in the Northerly Area.
- Simulated drainflow from the Northerly drainage-impaired area was increased by 15,400 AF/year to account for uncontrolled discharges into the drainage systems (URS 2002).

Total annual drainflow estimated for the In-Valley Disposal Alternative for the Northerly Area and Westlands are 35,200 AF/year and 40,562 AF/year, respectively, corresponding to a drainflow of 0.55 AF/tiled acre in the Northerly Area and 0.24 AF/tiled acre in Westlands.

4.2 DRAINWATER REDUCTION MEASURES

Reclamation found three on-farm drainwater reduction measures (source control) to be cost-effective in the 2002 PFR: drainwater recycling, shallow groundwater management, and seepage reduction. These measures continue to be used to estimate drainage production but have been supplemented with irrigation efficiency improvements and land retirement.

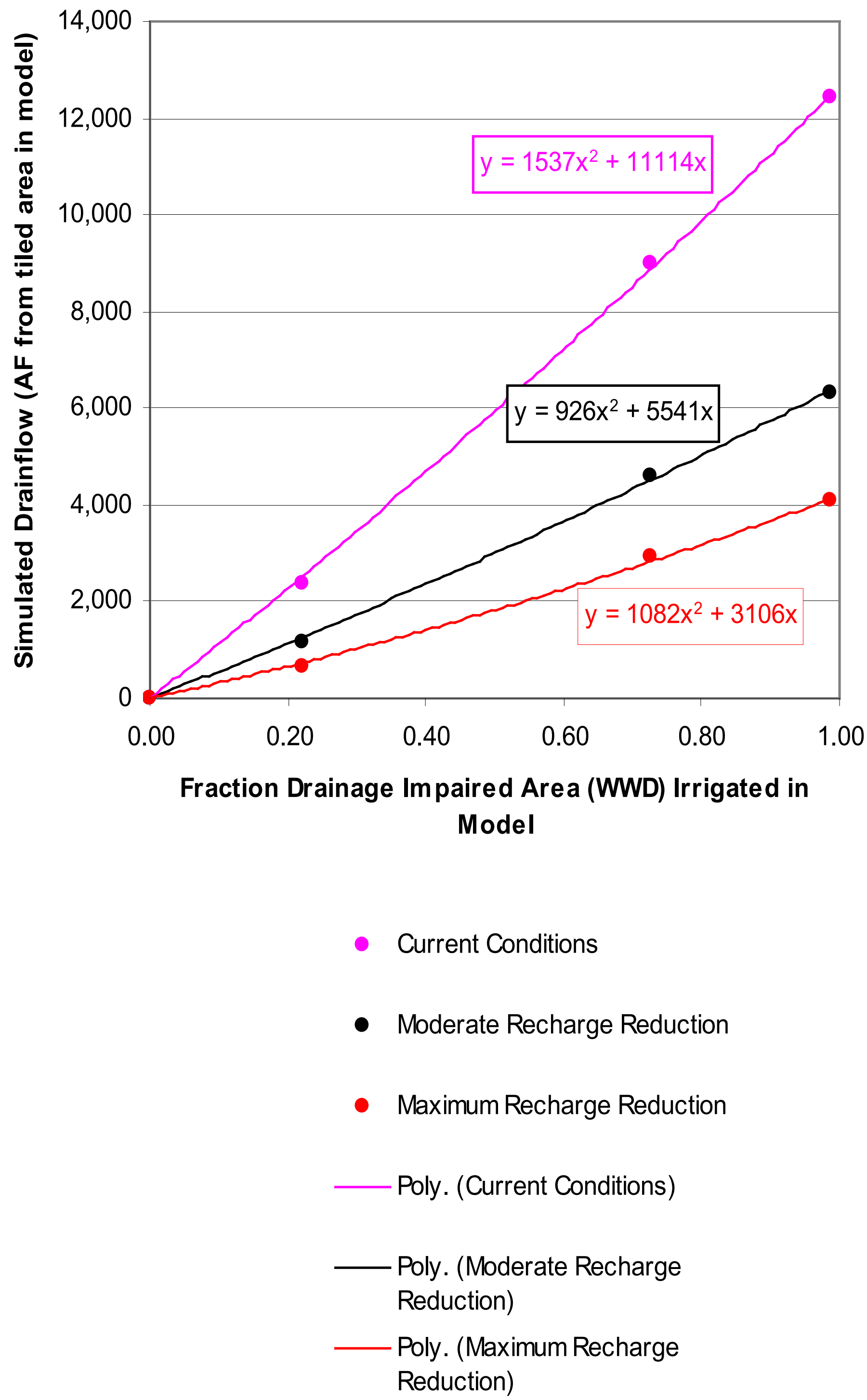
4.2.1 Land Retirement

The hydrologic effects due to mandatory retirement of various land areas were investigated. Various amounts of lands were retired in the model in 2005, and the annual changes in groundwater storage, water table depths, and resulting drainflows were simulated. As a result of land retirement, irrigation ceases on the retired lands and, consequently, groundwater pumpage and surface-water deliveries are discontinued. The simulated pumping rate beneath retired lands also becomes zero, but the pumping rate beneath active lands was increased to maintain a constant pumping rate of 175,000 AF/year within Westlands. The Technical Team then developed a relationship between the fraction of drainage-impaired land that was retired and the simulated drainflow and area requiring drainage systems in the remaining farmed area. The results of these relationships are shown on Figures 4-4 and 4-5. The results of the land retirement drainflow analysis for Westlands are shown in Table 4-2. The results indicate the scaled annual drainflow rate per tiled area is similar for all alternatives, ranging from 0.24 to 0.26 AF/tiled acre, with the exception of the scenario that retires all drainage-impaired areas, which resulted in no drainflow. For the Northerly Area, only one land retirement scenario was modeled (retirement of Broadview Water District). However, the model indicated land retirement in Westlands did have a small effect on drainflow rates in the Northerly Area. The resulting drainage flow rates in the Northerly Area are 0.47 to 0.55 AF/tiled acre/year.

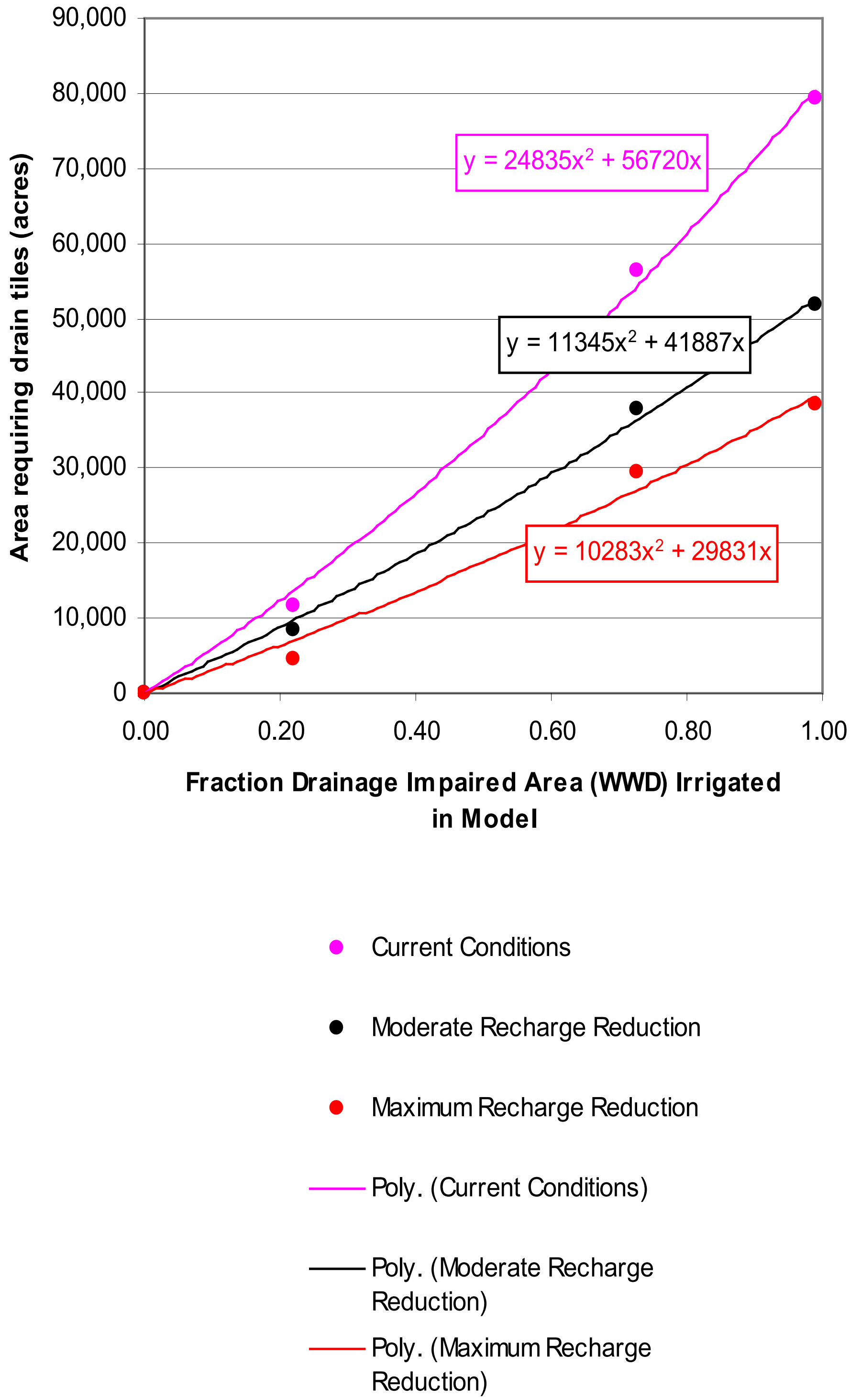
Table 4-2
Simulated 2050 Drainflow for Different Levels of Land Retirement – Current Recharge

	Retired (Westlands)		2050 Westlands Drainflow (AF/yr)		2050 Westlands Collector System Area (acres)		2050 Drainflow (AF/tiled acre)	
Scenario	**Acres**	**Fraction of Drainage-Impaired Area Irrigated**	**Model**	**Scaled**	**Model**	**Scaled**	**Westlands**	**Northerly Area***
In-Valley	57,141	0.81	9,989	40,562	62,083	168,066	0.24	0.55
Groundwater Quality	88,578	0.70	8,573	34,811	52,147	141,169	0.25	0.55
Water Needs	185,000	0.38	4,441	18,035	25,116	67,993	0.26	0.53
Maximum Retired	298,238	0.00	0	0	0	0	0.00	0.47

*Northerly Area drainflow rate does not include the approximately 15,400 AF of uncontrolled discharge. The total drainflow volume is, therefore, equal to the drainflow rate multiplied by 36,000 acres tiled plus the uncontrolled discharge.



HYDROFOCUS INC. Solutions for Land and Water Resources	Relationship Between Irrigated Area and Simulated Drainflow in 2050 for Different Recharge Rates	Figure 4-4
PROJECT: 5517	DATE: 4/22/04	



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Relationship Between Irrigated Area and Simulated Area Requiring Drainage Systems in 2050 for Different Recharge Rates

Figure 4-5

PROJECT: 5517

DATE: 4/22/04

4.2.2 Irrigation Efficiency

A similar analysis was also performed to determine how improvements to irrigation efficiency would change drainflow rates. For this analysis, water table recharge rates used in the model were reduced to simulate improved irrigation efficiencies. Similar to the previous analysis, relationships were developed between the fraction of land in the drainage-impaired area remaining in production and the predicted drainage rates for two additional levels of water recharge. Results of the modeling are shown in Tables 4-3 and 4-4. See also Section 3.3.10.3 for further discussion of analysis of deep percolation rates.

Table 4-3
Simulated 2050 Drainflow – Moderate Recharge Reduction

	Retired (Westlands)		2050 Westlands Drainflow (AF/yr)		2050 Westlands Collector System Area (acres)		2050 Drainflow (AF/tiled acre)	
Scenario	**Acres**	**Fraction of DIA Irrigated**	**Model**	**Scaled**	**Model**	**Scaled**	**Westlands**	**Northerly Area***
In-Valley	57,141	0.81	5,085	20,647	41,276	111,739	0.18	0.42
Groundwater Quality	88,578	0.70	4,353	17,676	25,053	94,893	0.19	0.42
Water Needs	185,000	0.38	2,237	9,085	17,540	47,482	0.19	0.40
Maximum Retired	298,238	0.00	0	0	0	0	0.00	0.36

*Northerly Area drainflow rate does not include the approximately 14,000 AF of uncontrolled discharge. The total drainflow volume is, therefore, equal to the drainflow rate multiplied by 48,000 plus the uncontrolled discharge. Drainflow reduction due to recharge reductions in Northerly Area lands located outside of the San Luis Unit (i.e., Firebaugh Water Budget Subarea in Table A-2) were estimated using model results for simulated recharge reductions in lands located within the San Luis Unit land (i.e., the Panoche and San Luis Water Budget Subareas in Table A-2).

Table 4-4
Simulated 2050 Drainflow – Maximum Recharge Reduction

	Retired (Westlands)		2050 Westlands Drainflow (AF/yr)		2050 Westlands Collector System Area (acres)		2050 Drainflow (AF/tiled acre)	
Scenario	**Acres**	**Fraction of DIA Irrigated**	**Model**	**Scaled**	**Model**	**Scaled**	**Westlands**	**Northerly Area***
In-Valley	57,141	0.81	3,218	13,067	30,836	83,476	0.16	0.29
Groundwater Quality	88,578	0.70	2,718	11,038	26,053	70,529	0.16	0.29
Water Needs	185,000	0.38	1,335	5,422	12,809	34,675	0.16	0.28
Maximum Retired	298,238	0.00	0	0	0	0	0.00	0.25

*Northerly Area drainflow rate does not include the approximately 12,600 AF of uncontrolled discharge. The total drainflow volume is, therefore, equal to the drainflow rate multiplied by 48,000 plus the uncontrolled discharge. Drainflow reduction due to recharge reductions in Northerly Area lands located outside of the San Luis Unit (i.e., Firebaugh Water Budget Subarea in Table A-2) were estimated using model results for simulated recharge reductions in lands located within the San Luis Unit land (i.e., the Panoche and San Luis Water Budget Subareas in Table A-2).

These results were used to develop a cost/benefit analysis for land retirement and improvements in irrigation efficiencies (Section 3.3).

4.2.3 Other On-Farm Measures

Drainage reduction from other regional and on-farm source control measures was previously analyzed in the PFR. The drainage reduction (source control) measures identified as cost effective in the PFR included seepage reduction, regional recycling, and shallow groundwater management. The on-farm, in-district drainwater reduction actions are not components of the drainage service alternatives to be implemented by Reclamation. Rather, they represent the assumptions Reclamation has made regarding the conditions of the area to be served and the reasonable actions that could be implemented by districts within the area to be served in order to estimate a reasonable drainage quantity and quality for the future once drainage service is provided. Although drainwater reduction actions other than the ones selected have been proposed in the Westside Regional Drainage Plan and could be implemented to reduce drainage flows (e.g., shallow groundwater pumping), it was determined that they were either not cost effective compared to the disposal facilities, or it was not reasonable to assume that they would be implemented due to the uncertainty regarding the effectiveness of the action. Shallow groundwater pumping shows promise for reducing drainflows. However, additional information is needed to demonstrate its practical feasibility, including the potential uses for the pumped groundwater.

For this analysis, drainwater reduction from regional recycling and shallow groundwater management were scaled from the estimates in the PFR, based on the size of the drainage collector area for the different land retirement alternatives. The benefit of lining water supply canals in the Northerly Area for seepage reduction was shown as a reduction of 3,200 AF/year in the Unit and 4,200 AF/year in the entire Northerly Area.

To estimate the current cost-effectiveness of these source control measures, the updated drainage treatment and disposal costs for each AF of drainwater treated were compared to costs per AF of drainwater avoided due to the on-farm and regional source control measures. The previously selected source control measures were determined to be cost-effective, given the new information on cost for treatment and disposal (Table 4-5). The annual savings per AF varies from $38 for drainwater recycling up to $154 for seepage reduction.

Table 4-5
Cost-Effectiveness Analysis of Drainwater Reduction Measures

Project Feature	Net Drainage Delivered to Reuse Areas (AF)	Estimated Capital Cost ($)	Estimated Operation/ Maintenance/ Replacement Cost ($)	Total Annual Equivalent Costs ($)
Alternative Costs with Source Reduction Measures				
Drainwater Recycling	59,805	553,492,000	14,255,000	
Shallow Groundwater Management	59,805	553,492,000	14,255,000	
Seepage Reduction	59,805	553,492,000	14,255,000	
Alternative Costs without Source Reduction Measures				
Drainwater Recycling	70,573	551,004,000	14,812,000	
Shallow Groundwater Management	64,875	567,639,000	14,081,000	
Seepage Reduction	63,005	555,315,000	14,638,000	
Difference Attributable to Source Reduction				
Drainwater Recycling	(10,768)	$2,488,000	($557,000)	
Shallow Groundwater Management	(5,071)	(14,147,000)	174,000	
Seepage Reduction	(3,200)	(1,823,000)	(383,000)	
Annual Equivalent Cost of Source Reduction				
Drainwater Recycling		$149,649	($557,000)	($407,351)
Shallow Groundwater Management		(850,920)	174,000	(676,920)
Seepage Reduction		(109,651)	(3893,000)	(492,651)
Annual Savings per AF of Source Reduction				
Drainwater Recycling		($14)	$52	$38
Shallow Groundwater Management		$168	($34)	$133
Seepage Reduction		$34	$120	$154

Interest Rate 5.6250%
Project Life (years) 50

4.3 DRAINAGE QUALITY

Revised estimates of drainwater quality from farmed lands and reuse areas were developed to enable calculation of discharge water quality for each land retirement and disposal alternative. The revised estimates will be used in the EIS to evaluate effects on surface- and groundwater resources.

4.3.1 Drainwater Quality

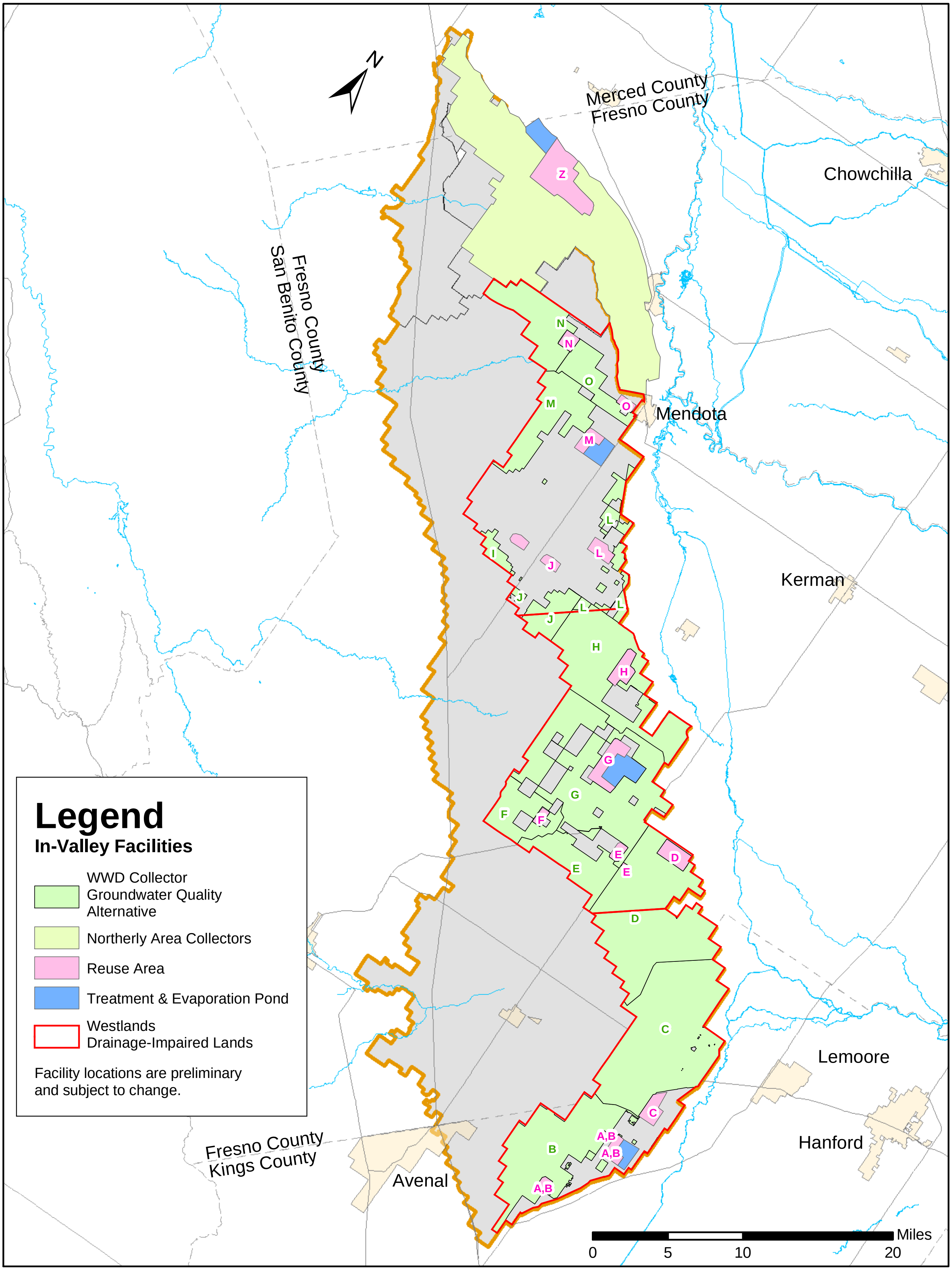
The groundwater quality map developed by Swain (1990) was updated to allow estimation of mean concentrations and uncertainty in drainwater quality by drainage subarea and for reuse areas within the subareas. Because the previous groundwater quality maps provided only a concentration range for different regions, a specific mean concentration for a given region could not reliably be estimated. This specific mean concentration is required to allow evaluation of the effects of both retiring lands and using specific lands for reuse facilities.

Updated groundwater quality maps were produced through geostatistical techniques (block kriging) of mean or median concentrations measured in shallow groundwater wells using data collected in the 1980s. Results from the 2002 groundwater sampling showed no consistent changes in groundwater quality relative to 1980s results. Maps were produced for total dissolved solids (TDS), Se, boron (B), and molybdenum (Mo). These estimated groundwater concentrations were compared to water quality measured in sumps during the same time period to determine if a consistent bias was present in the predicted concentrations. No bias was apparent from the comparison allowing the use of the predicted groundwater concentrations as an estimate of drainwater concentration. Block kriging was then used to estimate average concentrations for each 5,000- by 5,000-meter grid cell in the drainage-impaired area. Results from the block kriging were used to calculate mean concentrations for each subarea and for reuse areas. Estimates of the hydraulic conductivity of each 1-mile grid cell in the area covered by the Belitz groundwater model (Westlands North and most of the Northerly Area) were used to scale the estimated mean concentration to account for differences in drainage yield. Standard error from the block kriging was used to estimate the upper 95th percentile confidence limit of the means and the scaled means for each subarea (calculated as mean + [2 × standard error]).

Predictions for farmed lands in the Northerly Area were compared to measured values in sumps to provide a further check on the analysis. The concentrations in shallow groundwater for the farmed and reuse areas were used with the predicted flow rates and project components (reuse, Se treatment, RO treatment) for each disposal alternative to develop a flow-weighted concentration for each disposal alternative.

The subareas used to calculate average water quality are shown on Figures 4-1 In-Valley Alternative (in Section 4.1.1), 4-6 Groundwater Quality Land Retirement Alternative, and 4-7 Water Needs Land Retirement Alternative. The subareas were identified by the Technical Team and included farmed lands (shown as collector areas) and reuse areas for all action alternatives, and evaporation basins for the In-Valley Disposal Alternative only. Retired land areas were removed from collector areas for each of the land retirement alternatives. Figures 3-2, 3-3, and 3-4 (Section 3.4) show the location of the collector areas and existing retired lands. New retired lands include land acquired by Westlands and other gray-colored areas within the drainage-impaired area.

Existing and potential future reuse areas were delineated based on preliminary reconnaissance performed by Reclamation, and then these acreages were removed from drainage-impaired areas. The mapped reuse areas are larger than the areas required for drainage service but are assumed to be representative of potential reuse areas for water quality estimation purposes.



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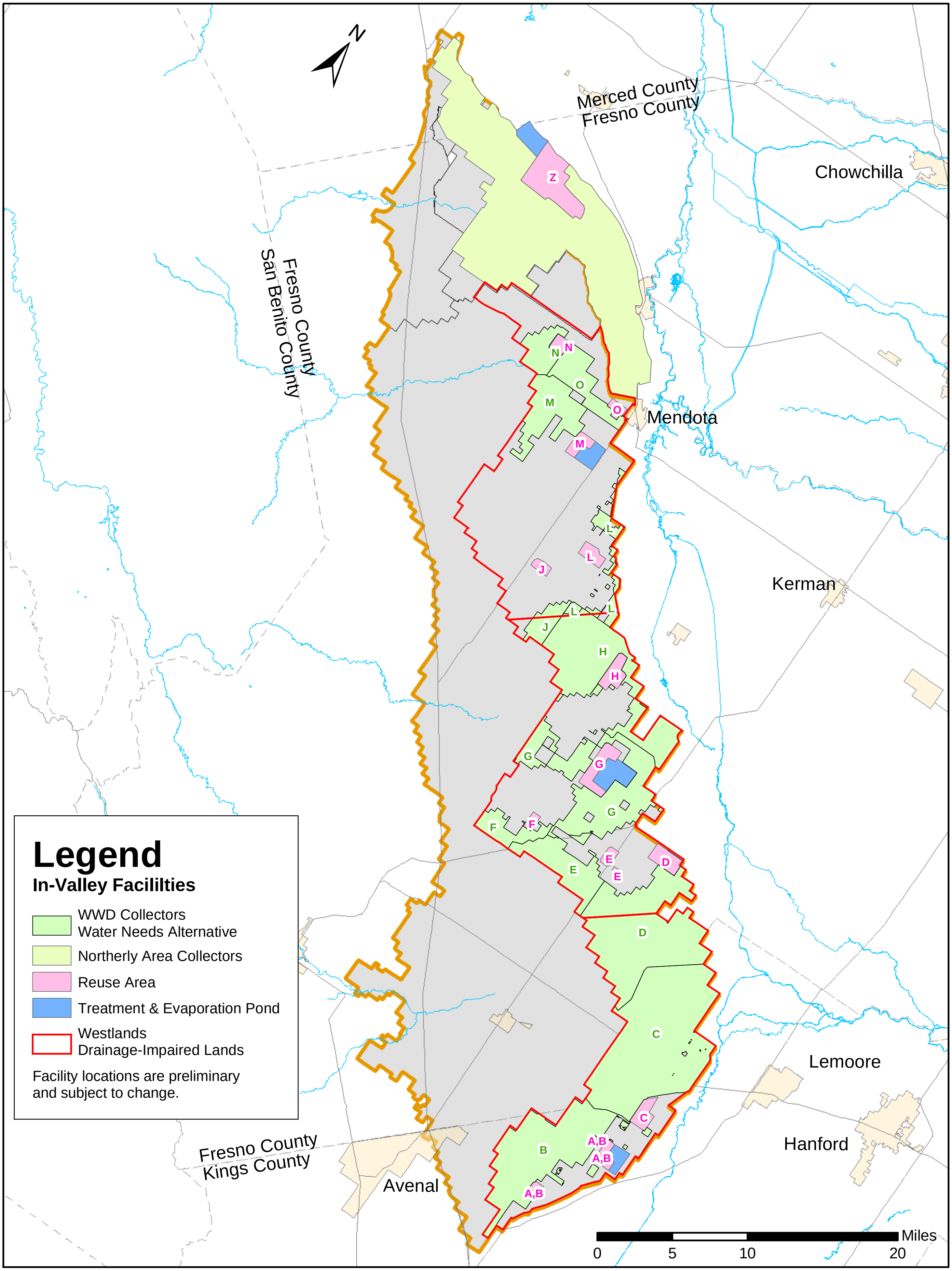
URS	San Luis Drainage Feature Re-evaluation 17324004	Drainage and Reuse Areas In-Valley/Groundwater Quality Land Retirement Alternative	Figure 4-6



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URS	San Luis Drainage Feature Re-evaluation 17324004	Drainage and Reuse Areas In-Valley/Water Needs Land Retirement Alternative	Figure 4-7

4.3.2 Results

Concentrations for constituents other than TDS, Se, B, and Mo have been estimated from TDS concentrations for all three Westlands subareas by adjustment with a scaling factor. The scaling factor for each constituent in each subarea was calculated as a ratio of the TDS concentration (from the geostatistical analysis for each subarea) to the respective constituent monitored in the Westlands North area. Table 4-6 is a summary of water quality in each subarea.

Table 4-6
Drainwater Quality from Farmed Lands

Constituent	Units	Report of Waste Discharge Westlands North [1]	Westlands North Best Available Data[2]	Westlands Central[2]	Westlands South[2]	Northerly Area[4]
Sodium	mg/L	2,200	1,700	1,300	1,600	600
Potassium	mg/L	7	7	6	7	9.2
Calcium	mg/L	560	440	340	410	290
Magnesium	mg/L	270	200	150	190	93
Hardness	mg/L	NA	NA	NA	NA	1100
Alkalinity	mg/L	200	200	151	180	170
Sulfate	mg/L	4,700	3,700	2,900	3,500	1,500
Chloride	mg/L	160	1,000	780	950	550
Nitrate (NO_3)	mg/L	210	240	180	220	44
Nitrate (N)	mg/L	48	53	41	50	10
Ammonia	mg/L	0.01	NA	NA	NA	1
Silica	mg/L	37	37	29	35	NA
Bicarbonate	mg/L	NA	230	170	210	170
Carbonate	mg/L	NA	NA	NA	NA	3.6
Bromide	mg/L	1.6	1.6	1.2	1.5	2.2
TDS	mg/L	9,900	9,300	7,100	8,700	4,000
Total Suspended Solids	mg/L	10	10	8	9	NA
Total Organic Carbon	mg/L	9.5	9.5	7	9	10
Carbon on Demand	mg/L	30	NA	NA	NA	NA
Biological Oxygen Demand	mg/L	3	3	2	3	NA
Temp	C	18	18	NA	NA	NA
pH		8.2	7.7	7.7	7.7	8.2
Boron	µg/L	15,000	10,000	6,700	7,700	9100
Se	µg/L	230	100	60	20	130
Strontium	µg/L	6,400	6,400	5,000	6,000	NA
Iron	µg/L	150	150	120	140	NA
Molybdenum	µg/L	72	68	110	220	34
Aluminum	µg/L	NA	NA	NA	NA	NA
Arsenic	µg/L	NA	3	2	3	8.2
Cadmium	µg/L	<1	37	29	35	NA
Chromium	µg/L	20	32	25	30	5.9
Copper	µg/L	10	10	8	9	3.4
Lead	µg/L	<1	1	1	1	4.8

Table 4-6
Drainwater Quality from Farmed Lands

Constituent	Units	Report of Waste Discharge Westlands North [1]	Westlands North Best Available Data[2]	Westlands Central[2]	Westlands South[2]	Northerly Area[4]
Manganese	µg/L	10	10	8	9	2
Mercury	µg/L	<0.1	NA	<0.1	NA	0.2
Nickel	µg/L	20	20	15	19	5.3
Silver	µg/L	1	1	1	1	NA
Zinc	µg/L	10	10	8	9	2.4

[1]CH2M Hill 1985.
[2]Westlands North, South, and Central data are estimated by scaling geostatistical analysis by a ratio of TDS concentrations from the kriging analysis to the measured concentrations of each constituent in each subarea.
[3]Concentrations of lead, copper, and mercury were reported to be less than the detection limits.
[4]Northerly Area concentrations from flow-weighted average of measured sumps for TDS, B, Se, and Mo concentrations from kriging analysis; other data from Grassland Bypass EIS (Reclamation 2001c).
[5]Flow-weighted averages are based on preliminary flow rates for subareas and need to be updated.

The water quality of the perched groundwater under the reuse areas is expected to gradually change due to the perched aquifer being replaced by the applied drainwater percolating past the root zone. The quality of the discharged drainwater would then become that of the applied drainwater, which is further concentrated by the fraction leached (assuming that the salt, B, and Se mass is conserved).

Table 4-7 shows the predicted TDS, Se, B, and Mo concentrations in shallow groundwater for farmed lands (after removal of retired lands, reuse areas, and evaporation basins) in each drainage subarea. Results for farmed lands in Westlands were developed from the 95th percentile upper confidence limit of the scaled mean concentration estimated using kriging described above. Scaled mean concentrations were generally one-half of the upper 95th percentile values. Results for the shallow groundwater in farmed lands from the Northerly Area were taken from flow-weighted average sump concentrations measured in the Northerly Area in 1999 for TDS, B, and Se. Because the values from the Northerly Area are measured values with lower uncertainty than the predicted values, the average rather than the 95th percentile upper confidence limits of the average values were used. Because no measured data were available, results for Mo were from the 95th percentile upper confidence limit of the scaled mean concentration estimated using the kriging described above.

Table 4-7
In-Valley Alternative Drainage Area Groundwater Quality[1]

Drainage Area	Se (µg/L)	TDS (mg/L)	B (µg/L)	Mo (µg/L)
Northerly Area[2]	130	4,000	9,100	34
Westlands North	100	9,200	9,800	87
Westlands Central	58	7,100	6,700	109
Westlands South	15	8,700	7,700	219

[1] Calculated as 95th percent upper confidence limit of average concentration using kriged groundwater well data.
[2] Northerly Area drained area groundwater for Se, TDS, and B based on average 1999 sump monitoring data from Panoche, Pacheco, and Charleston drainage districts.

Table 4-8 shows the predicted average initial groundwater quality for the reuse areas. These values are the concentration in shallow groundwater predicted from the kriging analysis prior to applying drainwater.

Table 4-8
Reuse Area Initial Groundwater Quality*

Reuse Area	Se (µg/L)	TDS (mg/L)	B (µg/L)	Mo (µg/L)
Northerly Area	140	14,700	25,900	70
Westlands North	154	13,550	15,000	150
Westlands Central	62	7,250	6,250	200
Westlands South	19	12,200	10,000	400

*Calculated as 95th percent upper confidence limit of average concentration using kriged groundwater well data.

Table 4-9 shows the theoretical highest concentration in shallow groundwater under the reuse area after application of drainwater for many years. These values were calculated from the predicted drainwater quality by assuming all constituents were conserved in the drainwater but the volume of water was reduced by 73 percent due to reuse area crop use and evaporation.

Table 4-9
Reuse Area Theoretical Final Groundwater Quality*

Reuse Area	Se (µg/L)	TDS (mg/L)	B (µg/L)	Mo (µg/L)
Northerly Area	490	15,000	34,000	130
Westlands North	370	34,000	38,000	250
Westlands Central	220	26,000	25,000	320
Westlands South	57	28,000	28,000	660

*Calculated as drainage area groundwater/0.27 leaching factor, assuming constituents are conserved.

In practice, the quality of the water removed from the reuse areas changes over time and will be a mixture of initial groundwater and the theoretical groundwater quality. To reflect this process, Table 4-10 presents the average of initial groundwater and theoretical groundwater quality as an estimate of the final quality of drainage that is expected out of the reuse facilities.

Table 4-10
Reuse Area Likely Final Groundwater Quality*

Reuse Area	Se (µg/L)	TDS (mg/L)	B (µg/L)	Mo (µg/L)
Northerly Area	320	15,000	30,000	100
Westlands North	270	24,000	26,000	250
Westlands Central	140	17,000	16,000	300
Westlands South	45	22,500	20,000	600

*Calculated as average of initial and theoretical final reuse area quality.

Table 4-11 shows the effect of RO treatment on water quality. Concentrations were increased by a factor of two for Se, TDS, and Mo based on the use of single-pass RO. Boron concentrations in RO brine were 40 percent of the reuse area concentrations based on previous performance of RO systems operated in Panoche Drainage District and elsewhere. RO is estimated to result in 80 percent of B passing through to the product water, with 20 percent remaining with the brine. The 20 percent concentration is contained within half the volume of water resulting in concentrations that are 40 percent of the starting concentration.

Table 4-11
Initial Brine Effluent from Reverse Osmosis Treatment

Reuse Area	Se (µg/L)	TDS (mg/L)	B (µg/L)	Mo (µg/L)
Northerly Area	280	29,400	10,360	140
Westlands North	310	27,100	6,000	300
Westlands Central	120	14,500	2,500	400
Westlands South	40	24,400	4,000	800

Following Se treatment, Se concentrations are estimated to be less than 10 µg/L based on observed performance in testing at Panoche and Westlands.

Tables 4-12 and 4-13 show a similar analysis for the final water quality that is expected for each disposal location. These predictions use the best estimate of the final groundwater quality under the reuse areas after long-term irrigation with drainwater (Table 4-9) as the basis for the estimates rather than the initial water quality currently under reuse areas. Based on previous modeling conducted by Western Resource Economics in the PFR, the time needed to reach final water quality from the reuse areas is estimated to be approximately 20 to 25 years.

Table 4-12
Final Brine Effluent from Reverse Osmosis Treatment

Reuse Area	Se (µg/L)	TDS (mg/L)	B (µg/L)	Mo (µg/L)
Northerly Area	640	30,000	12,000	200
Westlands North	540	48,100	10,000	500
Westlands Central	275	34,000	6,000	600
Westlands South	90	45,000	8,000	1,200

Table 4-13
Final Effluent from Selenium Treatment to Evaporation Basins

Evaporation Basin Location	Se (µg/L)	TDS (mg/L)	B (µg/L)	Mo (µg/L)
Northerly Area	10	30,000	12,000	200
Westlands North	10	48,100	10,000	500
Westlands Central	10	34,000	6,000	600
Westlands South	10	45,000	8,000	1,200

4.3.3 Predictions for Land Retirement Alternatives

The In-Valley/Groundwater Quality Land Retirement Alternative and the In-Valley/Water Needs Land Retirement Alternative are partial land retirement alternatives that retire farmed lands with the highest Se concentration in shallow groundwater. Drainwater quality predictions were developed for these alternatives by removing the lands from the collector system and recalculating the zonal statistics for the remaining lands in production.

Results of the Se analysis are shown in Table 4-14 for the In-Valley Disposal Alternative, In-Valley/Groundwater Quality Land Retirement Alternative, and the In-Valley/Water Needs Land Retirement Alternative.

Table 4-14
Initial and Final Selenium Concentrations Entering Selenium Treatment System for In-Valley and Land Retirement Alternatives

Alternative	In-Valley		Groundwater Quality Land Retirement[1]		Water Needs Land Retirement[2]	
Disposal Location	Initial	Final	Initial	Final	Initial	Final
Westlands North Evaporation Basin	308	543	263	380	242	142
Westlands Central Evaporation Basin	124	275	125	276	123	124
Westlands South Evaporation Basin	38	90	36	97	36	48

[1]Lands with Se concentrations in shallow groundwater greater than 50 ppb are retired.
[2]Lands with Se concentrations in shallow groundwater greater than 20 ppb are retired.

The tables show the initial and final Se concentrations in drainwater after reuse and RO but prior to Se treatment. Initial Se concentrations are driven by the initial quality of groundwater under the reuse areas and are independent of the lands retired. Compared to the In-Valley Disposal Alternative, final Se concentrations into the Westlands North Se treatment system are predicted to decrease by 30 and 74 percent for the Groundwater Quality and Water Needs Land Retirement Alternatives, respectively. For the Groundwater Quality Land Retirement Alternative no decreases in Se concentration into the Westlands Central and South treatment systems are predicted because the retired lands are contained only within the Westlands North subarea. For the Water Needs Land Retirement Alternative, Se concentrations into the Westland Central and South treatment systems are predicted to decrease by 55 and 65 percent, respectively, compared to the In-Valley Disposal and Groundwater Quality Land Retirement Alternatives.

In addition to lowering the total flow to be treated and disposed, retiring lands with high Se in shallow groundwater and lowering the Se concentrations entering the Se treatment system may decrease the cost of the system. However, no performance data are presently available for drainwater at lower concentrations to determine the potential cost savings of retiring lands with high Se concentrations.